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Learning to Make Systematic Decisions

Decision-making tasks place science in a meaningful societal context in a case-based environmental science course

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How do communities deal with the needs of a growing population? How do they manage limited resources like land, energy, and water? How do they balance the needs of humans against the needs of native ecosystems? Our curriculum approach confronts these questions and more by embedding science learning in the context of realistic societal decisions. This approach uses decisions as a context to motivate and guide science learning, while simultaneously teaching students to make systematic decisions about issues with societal implications. In this article, we describe why a teacher may want to use decision making as a teaching strategy, outline a structure for teaching decision making, and provide an example of how we have integrated decision making with content in an environmental science curriculum. We use the following example: How would your community respond if the only suitable location to build a new school is the habitat for a threatened species of tortoise?

Teaching decision making

While teaching students science content and inquiry practices is important, it is not sufficient to prepare students to make well-reasoned decisions (Arvai et al. 2004); they must also learn decision-making skills. To be effective, instruction on decision making should be based on an understanding of how thoughtful decisions are made and common pitfalls of the decision-making process (Allen 2000; Arvai et al. 2004).

Decisions we make in our communities today have far-reaching, even global, impact. For example, 21st-century society members must make personal and political decisions about diet, lifestyle, healthcare, transportation, housing, and consumption that have personal, societal, and environmental impacts. To make decisions wisely, members of modern society must assess the implications of a decision, such as costs, and the impact on individuals, communities, and the environment. They must also evaluate implications systematically in light of their values.

To help students develop these skills, we have created an instructional approach based on a decision-making process that we call the Stakeholder Consequences Decision-Making (SCDM) process (see "The SCDM process"). This instructional approach has four primary goals:

- Provide students with a meaningful context for understanding science and scientific practices.
- Help students learn to establish decision-making criteria and identify the consequences of a decision.
- Provide students with a framework for applying personal values to their understanding of consequences in order to make a decision.
- Provide teachers with an opportunity to assess students' understandings of science and decision making.

By providing a structure that separates the process of assessing consequences based on science and making a decision by applying values to that assessment, teachers and students can focus on developing and using scientific evidence, while they see how individuals with different values can make and justify different decisions based on the

same evidence. By structuring decision making as the creation of a sequence of artifacts representing the decision maker's reasoning, teachers can assess both a student's conceptual understanding of the relevant science and the thoroughness of his or her decision-making process.

Planning a new school

We use the following case to provide the focus for an eight-week introductory unit on populations, resources, and ecosystems: A community must decide how to build a new school on a plot of land that is habitat for a threatened species. This case is drawn from a yearlong high school course titled *Investigations in Environmental Science* that we have developed around the SCDM.

Introducing the school example at the beginning of the unit creates demand for understanding the science content. During the central part of the unit, students engage in a mix of learning activities designed to help understand the science content. For the culminating activity, students make and justify a decision about how to design the school. This approach to creating demand for understanding, constructing understanding, and applying understanding implements an instructional model called *Learning-for-Use* (Edelson 2001) that is based on contemporary research in cognitive science.

In designing the school, students must balance the interests of the community—including the students who will attend the new school—and the site's current ecosystem. In the following paragraphs and figures, student work illustrates how the decision-making process happens.

The scenario

At the beginning of the eight-week unit, students are introduced to a scenario in which they play the role of students in a fictitious school district in Florida that has outgrown its current building. As students in this district, they are asked to make a recommendation to the school board about the design and layout of the school facilities on its property (an example of the letter can be found with the online version of this article at *www.nsta.org/highschool#journal*). Students are presented with the basic requirements for the school building and given several options to consider, such as extra space to support a broader range of academic subjects; additional parking spaces to accommodate more students' cars; or a larger extracurricular activity complex, including athletic fields and space for performing arts. Students also need to preserve sufficient land to sustain a population of the gopher tortoises that already live on the site.

Populations, resources, and ecosystems

Over the course of the unit, students learn about the dynamics of the Florida Upland ecosystem where the gopher tortoise lives and the interdependencies of all of the plants and animals in the ecosystem. As a result, students learn that to protect the tortoises, they must protect habitat for all the plants and animals in the ecosystem, not just their burrows and feeding grounds.

The unit is structured around three central environmental science topic areas that provide the context for the Florida school decision: populations, resources, and ecosystems. For each of these, students learn about the topic in general—for example, human population trends

The SCDM process.

The SCDM process consists of four stages: establishing constraints and considerations; identifying consequences; assessing impacts on stakeholders; and weighing impacts on stakeholders.

Establishing constraints and considerations

The first stage of the SCDM process establishes basic criteria for the decision regarding desired outcomes. In our process, students identify two types of criteria: constraints and considerations. Constraints are essential outcomes, and considerations are desired outcomes (see Figure 1, p. 42 for examples of both). At this stage, some options may be eliminated based on failure to meet constraints, and the others may be ranked based on how they fare on considerations (Figure 2, p. 42).

Identifying consequences

In the second stage, students apply their understanding of the underlying science to assess the consequences of different options for the decision. To record consequences, students create a diagram called a cascading consequences chart, which is a diagram displaying chains of causes and effects stemming from a particular option (Figure 3, p. 43).

Assessing impacts on stakeholders

The third stage of the process is identifying the implications of these consequences on stakeholders, which can be people, other organisms, and even inanimate components of the physical environment. As with the previous stage, assessing impacts on stakeholders requires students to draw on their understanding of the relevant science. The impacts are recorded in a stakeholder impacts chart that asks students to identify the impact on each stakeholder, whether the impact is an intended goal or a side effect of the option, and whether the stakeholder is a knowing party to the decision (Figure 4, p. 44).

Weighing impacts on stakeholders

The final stage of the decision-making process includes weighing the impacts of the different options on stakeholders based on the decision makers' values. This portion of the process is also recorded in the stakeholder impacts chart. In this stage, students specify how important the interests of each stakeholder are to them and whether they believe negative impacts on a particular stakeholder are balanced by positive impacts on them or other stakeholders. This is the stage in the process when students bring in their values and see how different values can lead to different decisions.

We have developed guidelines for how to assess each element of the decision-making process. The three criteria that are used for assessing the artifacts that students create are completeness, accuracy, and quality. Whether and how each of these criteria apply to each artifact depends on the nature of the artifact.

FIGURE 1

An example of a group of students' constraints and considerations list.

(**Editor's note:** The student work in this and the following figures was selected by the authors to represent typical student work. It is reproduced here without alteration.)

Your Individual Constraints	Your Individual Considerations
(Each group member should first make a list of his/her constraints & considerations.	Then, as a group, you will make a group list)
Group Constraints (Minimum 2)	**Group Considerations (Minimum 3)**
• We would like to build a school that can handle 2,000 students total. • we believe that for the tortoises to survive for the next 200 years, we need at least 50 to live on this site and each one will need at least one acre of land for burrowing and foraging.	[redacted] • we could consider~~ate~~ more than one cafeteria • Consider more than two tennis courts seperate • consider practice rooms instead of shared practice rooms.

throughout the world and the United States—and in the local context—for example, population trends in Florida. The pedagogical approach mixes laboratory investigations, analysis of data using computational tools, discussions, readings, and written assignments.

Through the sequence of learning activities, students learn that the human population in Florida is growing primarily as a result of migration; that land is an increasingly scarce resource that is the focus of competition between human use for dwellings, food production, commerce, and ecological productivity; and that the gopher tortoise is a member of a complex set of ecological relationships that include food webs and other forms of interdependence.

For example, as part of the chapter on ecosystems, students map food chains for the Upland ecosystem, com-

FIGURE 2

Students calculate which options meet their constraints.

(**Editor's note:** The students' answer for option D is incorrect.)

Option Letter	Academic Space Size (8 or 16 acres)	Parking Size (4 or 12 acres)	Extra-curricular Size (12 or 24 acres)	TOTAL area used by school	River Acres (4 acres)	Total used by school & river	Tortoises need how much? (Acres)	Is it enough for the tortoises?	Does this option meet your other constraints? (Yes, No, or May'
A	16.	4	12	16 12 4 32 = 32	-4 acres	36	50	yes	yes
B	16	4	24	24 16 4 44 = 44	-4 acres	48	50	yes	yes
C	8	4	12	12 8 4 24 = 24	-4 acres	28	50	yes	yes
D	16	12	24	24 16 12 52	-4 acres	56	50	yes	yes
E	8	12	12	12 12 8 32 = 32	-4 acres	36	50	yes	yes

3. Which options are the best (don't violate your basic constraints)?
A & C

bine them into food webs, and then predict the effects of various disruptions to the food web. They also learn about how plants and animals in the ecosystem depend on each other. For example, gopher tortoises disperse seeds for plant species, and their burrows provide shelter for other animals from predators and fire.

Using SCDM in the Florida school example

At the conclusion of the unit, students apply their understanding of the specifics of the Florida context using the SCDM process to select and justify a decision.

Step 1: Establishing constraints and considerations

In the first step of the decision-making process, students identify constraints and considerations. The basic constraints come from the scenario: minimum space requirements for the school and the need to preserve a population of at least 50 gopher tortoises. In addition to these, students have the opportunity to add other considerations reflecting their values within the role-play, such as maximizing space available for the natural ecosystem, academic activities, parking for students, or extracurricular activities. Figure 1 shows that students want to have enough space for an additional cafeteria; practice rooms for music, which could be accommodated by a larger academic building; and tennis courts, which would be included in additional extracurricular space.

The following describes the assessment for Step 1. The completeness for a constraints and considerations list depends on whether students have captured all of the types of constraints and considerations described in the problem. The accuracy depends on whether students have captured the constraints and considerations as given to them in the problem, and the quality is determined by how well they justify their list. A scoring guide for the constraints and considerations list in the Florida school project can be found with the online version of this article at *www.nsta.org/highschool#journal*.

Once the constraints and considerations have been established, students identify options and begin to narrow them. They consider the different possible permutations of academic building size, parking capacity, and extracurricular facilities that are offered in the scenario and eliminate the ones that do not meet their constraints based on total space considerations (Figure 2).

FIGURE 3

A cascading consequences chart for the consequences that students identified for the option that includes extra space for academic and extracurricular facilities.

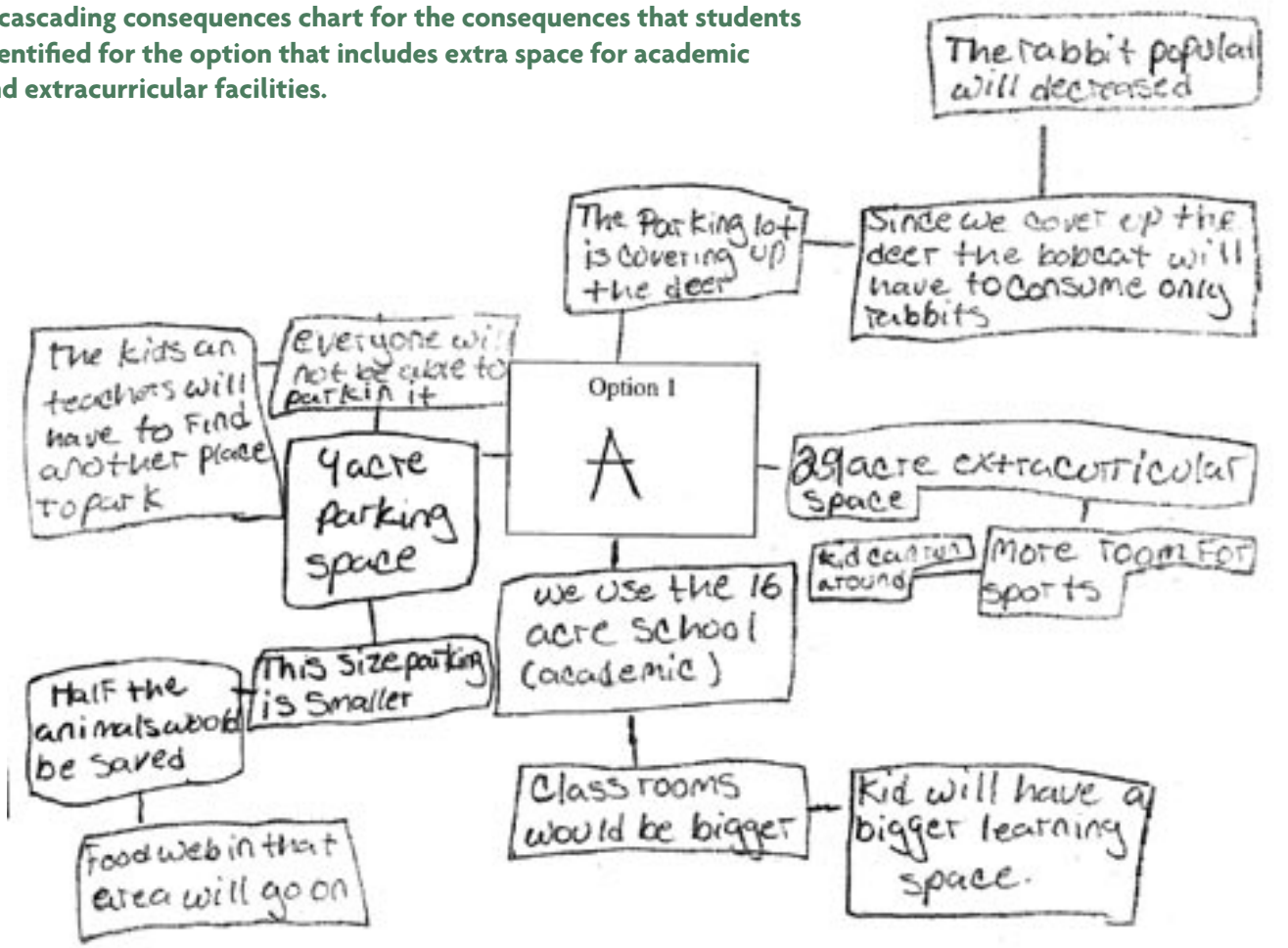

FIGURE 4

A stakeholder impacts chart.

(**Editor's note:** The students have failed to complete the final row in the table.)

Who are the stakeholders that will be affected by this action?	In what way(s) will they be affected?	+ or –	Is this effect the intended goal of the action or is it a side effect?	Has the stakeholder placed themselves in this position voluntarily and with appropriate understanding of the risks involved?	How important to YOU are the interests of this stakeholder? 1=very important 2= somewhat important 3=unimportant	If the effect is negative, do YOU feel it is directly offset by greater good elsewhere?
students	The students will have more space to learn and more supplies, as well as less room for parking and extracurricular.	+	Intended goal	~~yes~~ NO	1	
staff	The staff will have easier schedule but the parking will be tighter	+	Intended goal	~~yes~~ NO	2	
ecosystem	The building are killing of wildlife and taking away trees	–	side effect	no	1	
construction development staff	The will have more work for the construction space be limited for the parking area.	+	Intended goal	yes	2	
community	They school is bring more opportunity to the community	+	Intended goal	no	1	

Step 2: Identifying consequences

Students apply their understanding of ecosystem dynamics while identifying consequences. Using cutouts of building outlines and a paper map of the site, students identify possible locations for the facilities based on the options retained through the previous step. At this stage, students are asked to select three different site plans that meet their constraints and do well on their considerations. For each of these options, students create a cascading consequences diagram based on their understanding of both the ecosystem dynamics and the social system that includes the school (Figure 3, p. 43).

In assessing a cascading consequences chart, a teacher should check if it has the complete set of immediate consequences for each option and their subsequent impacts and the accuracy of the causal links in the chart (see the online version of this article at *www.nsta.org/highschool#journal* for a scoring guide).

Step 3: Assessing impacts on stakeholders

In this stage of the Florida school project, students create a stakeholder impacts chart that lists each of the entities that would be affected by the consequences they listed in their cascading consequences chart (Figure 4). The focus of the stakeholder chart is on the nature of the impacts of each option on each stakeholder, including whether they would be consciously and voluntarily placing themselves in the position to be affected. The stakeholders chart asks students to identify the stakeholders that will be affected by that option and then answer the following questions about the impacts of the option on each of the stakeholders:

- In what ways will the stakeholder be affected?
- Is this a positive or negative effect on them?
- Is this effect the intended goal of the action or is it a side effect?
- Has the stakeholder placed itself in this position voluntarily and with appropriate understanding of the associated risks?

The portion of the stakeholder impacts chart that students complete in Step 3 should be assessed for the completeness of the stakeholders list and the accuracy of the impacts identified for those stakeholders.

Step 4. Weighing impacts on stakeholders

After identifying these impacts, students are then ready for the final step in the decision-making process—applying personal values to the process of weighing the impacts of the decisions. Students begin this process by answering the following questions in the stakeholders chart:

- How important to you are the interests of this stakeholder?
- If the effect on this stakeholder is negative, do you feel that it is directly offset by greater good elsewhere?

Teachers should consider two aspects of quality when assessing this step: the consistency with which they apply their values and the quality of the justification for how they applied their values to weigh the importance of impacts. (A scoring guide for the stakeholder impacts chart in the Florida school project can be found with the online version of this article at *www.nsta.org/highschool#journal*).

Making and justifying a decision

Students conclude the decision-making process by evaluating the three options against each other, taking into account constraints, considerations, and stakeholder impacts. They are asked to justify their decisions in a report or presentation using the artifacts they created during the decision-making process.

The final decision and justification are assessed on the completeness of the account of the decision, the accuracy of the science behind it, and the quality of the justification.

Teaching and assessing the SCDM Process

Because of the complexity of decision making, we introduce students to the SCDM process in stages. Drawing on the cognitive apprenticeship approach (Collins, Brown, and Newman 1989) of modeling, scaffolding, coaching, and fading, we first introduce students to the process by modeling it. Next, we provide scaffolding for them to learn to conduct the process themselves by having them proceed step by step through a relatively simple decision with substantial guidance, or coaching, from the teacher. We continue to scaffold and guide them through their first complex decision—the Florida school decision, but in subsequent units we fade the scaffolding and coaching by asking them to make increasingly complex decisions with less and less structure and guidance.

In the Florida school unit, students' first exposure to the process is through a secondhand narrative describing how a fictitious young couple used the process to consider how many children they wanted to have. In their second exposure, students are guided step by step through the process of making a decision in which they are given all the information necessary to understand the consequences and stakeholder impacts in a short reading. The school decision described here is their third exposure, and, while the decision requires more complex and independent reasoning, we still provide them with a substantial amount of guidance and structure for the process. The fourth exposure, a complex decision with reduced scaffolding, asks students to consider if a coal-burning power plant should be built and where it should be located.

Assessment guidelines for each step in the Florida school project include scoring guides for each artifact that students construct in the course of making a decision. We have also created a set of environmental decision-making tasks to be used as external assessments of students' decision making. These one-period tasks present students with a realistic decision-making scenario and a set of background information, then ask students to make and justify a decision. In one scenario, students are asked to make a recommendation for a car purchase for a friend. In another, students are asked to advise a town on what type of housing development they should approve to meet the growing need for housing in that community.

Reflections

The SCDM process has been developed and revised through a series of field tests in a wide variety of high school settings. We have found this decision-making process to be accessible and engaging to a broad range of students. From a content learning perspective, the SCDM process offers students the opportunity to apply their content understanding in context and provides teachers with a window into their students' thinking. Equally important, it can help prepare students to make the complex decisions that they will be called to make throughout their lives. ■

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